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Collecting Representative Soil Samples for N and P Fertilizer Recommendations

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Abstract

Soil fertilizer recommendations in modern crop production rely on laboratory analysis of representative soil samples. Regardless on how soil samples are collected (grid points, management zones, or whole fields) the accuracy and precision of the fertilizer recommendation can be improved by considering the factors influencing nutrient variability. As producer's crop enterprise varies, it is recommended that producers select approaches that are suited for their operation. The objectives of this guide are to discuss how management influences nutrient variability and to provide insight into designing soil sampling protocols that provide accurate and precise fertilizer recommendations.

Introduction

A beginning point for fertilizer management is to collect a representative soil sample from a field, grid point, or management zone. A discussion on how to grid soil sample or developing management zones is beyond the scope of this guide and is available in Buchholz (2), Chang (3), Doerge (5), Ferguson and Hergert (6), Fleming et al. (7), Franzen (8), Franzen and Cihacek (9), Franzen and Kitchen (10), and Jacobsen (11). The four topics discussed in this guide are:

· Precision and accuracy of soil sampling;
· Previous management influence on accuracy and precision;
· Location of fertilizer bands; and
· General soil sampling recommendations.

Precision and Accuracy of Soil Sampling

A representative soil sample is one that adequately portrays the nutrient content of the area being sampled. Typically, it a composite of many cores collected from a specified area. If a representative sample is collected, then the soil test result represents the field average. Fertilizer recommendations based on the laboratory analysis of the soil sample may be inaccurate if representative samples are not collected. The quality of a recommendation can be described by two terms: precision and accuracy. Accuracy refers to bias (how close the calculated results are to the true results), while precision refers to the repeatability of fertilizer recommendations (18). Both precision and accuracy are influenced by how a sample is collected. The degree of precision (D) for a sampling approach can be estimated using the equation (15,17):

$$D^2 = (t_p{}^2)\,(s^2)\,/\,n \qquad [1]$$

where n is the number of soil cores collected, t_p, is the student t value associated with a specific probability level, s^2 is the variance, and D is the confidence interval of the average value. When using this equation, the units or dimensions used for s^2 and D^2 must be the same. The variance (s^2), a measure of variation, can be calculated using a computer spreadsheet. The t value can be obtained from a statistical table in most statistical books. A further discussion of this equation is beyond the scope of this paper and is available in Skopp et al. (15). Equation 1 shows that precision can be improved by increasing the number of samples (n) in the composite sample or by reducing the variance.

Previous Management Influence on Accuracy and Precision

The soil sampling protocol required to collect unbiased samples is influenced by how and when the fertilizer was applied. For example, Clay et al. (4) showed that one year after anhydrous ammonia was band applied to row middles in ridge and no-tillage systems, the spatial distribution of inorganic N looked like a Christmas tree, with the highest inorganic N concentrations located directly below the old fertilizer band (Fig. 1). This variation tends to decrease with time and tillage. In systems such as this, over-sampling N bands results in biased under-estimation of N fertilizer. Conversely, under-sampling N bands results in biased over-estimation of N fertilizer. Clay et al. (4) showed that a good approach to sampling these fields was to composite 15 to 30 cores collected from a zone located halfway between the row and the row middle.

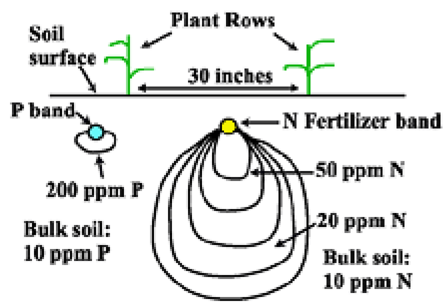

Fig. 1. A hypothetical diagram showing the influence of N and P fertilizer bands on nutrient variability. The P band was placed 2 inches below and to the side of the seed and the N band was located in the center of the interrow area. This diagram was based on the findings of Clay et al. (4) and Stecker et al. (16).

Lory and Scharf (12) had a different solution to the same problem. They recommended that the area between the row middle and the row be split into three equally sized zones that are 5 inches wide. One sample should be collected from each zone. This sampling procedure should be repeated at approximately 10 different areas in a field, resulting in 30 cores being combined into a single sample.

A third option offered by Blackmer et al. (1) was to collect soil samples in sets of eight cores that have various assigned positions relative to the past crop row. The first sample is collected in the row. After moving to another random location, the next core is collected 1/8 the distance between the row and the next row, and after moving to a different random location, the next core is collected ¼ between any two rows. This process is continued until the eighth core is collected 7/8 the distance between any two crop rows.

Similar research was conducted in no-tillage fields in Colorado and Kansas where P was band applied (13). This study found that if P band locations are known based on stalk or straw from past crop rows, then only one sample out of 20 should be collected from the band. In Missouri, Stecker et al. (16) reported that residual P concentrations in band-affected soil were 5 to 30 times greater than unaffected soil and that high levels remained within 3 inches of the band. Both of these studies showed that over-sampling the band increased the difference between the true soil P level and the measured value, which resulted in under-estimating the P fertilizer requirement. Based on results by Kitchen et al. (13), an equation for calculating the relative number of soil cores that should be collected from on- and off-band locations in wheat-fallow and wheat-sorghum rotations was developed. This equation was:

$$S = 8 \text{ (row spacing in inches) } / 12 \qquad [2]$$

where S was the ratio between the number of off- to on-band samples. This equation suggests that for a 30 inch row spacing, 20 samples should be collected off-band for every on-band sample collected ($S= 8\times30/12$).

Old farmsteads may also influence the accuracy and precision of the fertilizer recommendation (14). In many situations soil samples collected from old farmsteads have higher P levels than the rest of the field (Fig. 2). Elevated P levels may result from previous manure applications or old animal confinement areas. Including samples from these areas in the whole field composite sample may increase soil test results and the number of samples required to achieve a given level of precision (Table 1). Based on these results we recommend that whole field composite samples exclude areas where old homesteads or feedlots were located. Although the sampling strategies discussed above are distinctly different, they share the common goal of reducing sample bias, and are based on the observation that previous N and P management influences our ability to collect unbiased soil samples.

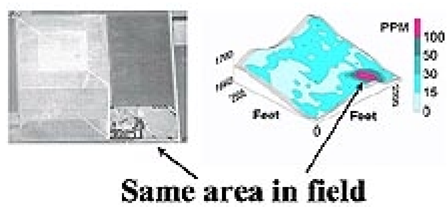

Fig. 2. Map of soil P superimposed on an elevation map (right) and a 1956 black and white photograph (left) of the same field (14).

Table 1. The influence of excluding the old farmstead from a whole-field composite sample on soil test results and, estimated using Equation 1, the number of soil cores (n) required for a given level of precision (± 3 ppm) (14).

	Sampling the whole field		**Excluding the old farmstead**	
Field	**Field average P** (ppm)	**Sampling requirement** (n)	**Field average P** (ppm)	**Sampling requirement** (n)
1	23	310	17	44
2	32	1648	16	36
3	21	258	16	15
4	42	900	20	143
5	7	9	6	1
6	7	7	7	4
7	10	66	6	2
8	40	409	27	89
9	10	36	7	7
10	13	26	12	16
11	21	99	18	90
12	16	121	12	71

Locating Fertilizer Bands

Locating the old N and P band is the first step in developing a sampling approach that minimizes biases and maximizes precision. When fertilizer bands are placed directly under the row or in row middles, the old rows can be used as markers for the fertilizer bands. Except in certain situations, it is easy to find N bands if anhydrous ammonia fertilizer bands are applied directly down row middles. One exception was revealed by a telephone survey of South Dakota fertilizer applicators. Many anhydrous ammonia applicators have an odd number of shanks. When these applicators are used in tandem with a planter (8-row planter followed by a 7-row fertilizer applicator), guess rows may not be fertilized. This planting and fertilizing strategy is used to minimize double fertilizing guess rows and to avoid running the fertilizer shank down planted rows.

Locating residual bands can be challenging when bands are not placed directly under the row or exactly between the rows. For example, if the P band is 2 inches to the right and below the seed, then locating the bands requires that planting direction be known (Fig. 3). If the planter is going in one direction the band will be on one side of the row, and if going in the opposite direction the band will be on the other side. In this situation, guess rows can contain either zero or two bands. These problems can be solved by:

· Not collecting soil samples from guess row; and
· Collecting a single core from either side of the same crop row.

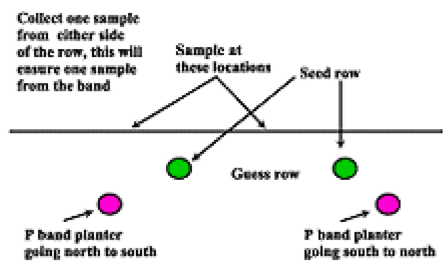

Fig. 3. The relative location of a P fertilizer band placed 2 inches below and to the side of the seed.

General Soil Sampling Recommendations

1. The sampling strategy should consider how fertilizer was applied and the tillage system used. A single sampling protocol will not work for all situations.
2. Crop producers should develop a diagram similar to that shown in Fig. 1 to identify the location of N and P fertilizer bands.
3. Sample areas where animals were confined separately from the rest of the field. Evidence of old homesteads and animal confinement areas can be seen in USDA-NRCS aerial photographs collected during the 1950s and 1960s. Many of these photographs are available from your local USDA-NRCR office or can be found in county soil survey manuals.
4. When possible, avoid sampling guess rows, as they may contain 0 or 2 fertilizer bands.
5. In tilled fields where N and P fertilizers were broadcast, randomly collect between 15 to 30 individual soil cores from each sampling zone.
6. In a reduced tillage system where nutrients are band applied, keep records on how, when, and where N and P fertilizers were applied. Use the following protocol for soil sampling when possible. For a 30-inch row spacing, collect only 1 core from the old residual P band for every 20 outside the P band. If P was banded 2 inches below and to the side of the seed, then collect one sample on each side of the row (2 inches from the row). This will insure that only one sample is collected from the P band. If N was banded halfway between the crop rows, then the remaining cores should be collected halfway between the row middle and the crop row. If P was banded below the seed, then collect one sample from the row and the remaining cores halfway between the row middle and the crop row.

7. If the N and P band locations are unknown, then collecting representative soil samples is difficult. The best way to address this problem is to find out as much as possible about the past fertilizer and manure practices. A sampling strategy, such as that proposed by Blackmer et al. (1), can be used if relatively little is known about a site. The Blackmer et al. (1) approach, as described earlier, is a mix of random (for landscape-scale variation) and targeted sampling (for short-scale variation from banding).
8. Soil from all cores should be crushed and thoroughly mixed before a subsample is removed for analysis.
9. The accuracy of the fertilizer recommendation is improved by increasing the number of individual cores included in a composite sample. A composite sample should contain at least 15 individual cores. More is better. Composite samples containing only 5 or 6 individual cores can result in misleading fertilizer recommendations.

Acknowledgements

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